MACHINERY'S DATA SHEETS
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No. 15

Heat and Steam
Steam and Gas Engines

PRICE 25 CENTS

CONTENTS

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MACHINERY'S DATA SHEET SERIES

COMPILED FROM MACHINERY'S MONTHLY DATA
SHEETS AND ARRANGED WITH
EXPLANATORY NOTES

No. 15

Heat and Steam
Steam and Gas Engines

CONTENTS

In the following pages are compiled a number of diagrams and concise tables relating to heat, steam, steam and gas engines, carefully selected from MACHINERY'S monthly Data Sheets, issued as supplements to the Engineering and Railway editions of MACHINERY since September, 1898. Additional tables also are included which are published here for the first time. In order to enhance the value of the tables and diagrams, brief explanatory notes have been provided wherever necessary. In a note at the foot of the tables, reference is made to the page on which the explanatory note relating to the table appears.

STEAM AND GAS ENGINES

Comparison of Thermometer Scales

There are three thermometers in common use, the Fahrenheit, the Celsius, and the Réaumur. The Fahrenheit thermometer is in general use in the United States and Great Britain, and in other English-speaking countries. The Celsius thermometer, commonly known as the Centigrade, is used for most scientific purposes, and in nearly all of the countries on the European continent. The Réaumur thermometer is largely used in Germany. On the scale of the Fahrenheit thermometer, the freezing point of water is taken at 32 degrees, and the boiling point at 212 degrees. On the scale of the Celsius or Centigrade thermometer, the freezing point is taken at zero (0 degree) and the boiling point at 100 degrees. On the scale of the Réaumur thermometer, the freezing point is taken at zero and the boiling point at 80 degrees.

The following rules may prove helpful in transferring temperatures in Centigrade and Réaumur to degrees Fahrenheit.

1. To change a temperature given in degrees Centigrade to degrees Fahrenheit, multiply the number of degrees Centigrade by nine-fifths, and add 32 degrees. The sum is the temperature in degrees Fahrenheit.

2. To change a temperature given in degrees Réaumur to degrees Fahrenheit, multiply the number of degrees Réaumur by nine-fourths, and add 32 degrees. The sum is the temperature in degrees Fahrenheit.

On page 4 is given a table for rapid comparison of thermometer scales for ordinary temperatures up to the boiling point of water. For example, a temperature of 34 degrees Centigrade, it will be seen from tnis table, corresponds to a temperature of 27.2 degrees Réaumur and 93.2 degrees Fahrenheit.

Properties of Saturated Steam

The amount of heat required for raising water to any given temperature and for transforming water into steam is measured in heat units or British thermal units. A British thermal unit is defined as the quantity of heat required to raise the temperature of one pound of water one degree F., at or near the temperature of maximum density of water (39.1 degrees F.).

On page 5 is given a table of the weight of water per cubic foot, and of heat units in water, for temperatures between 32 and 212 degrees F. The column of heat units gives the number of heat units required for raising the water to any given temperature from 32 degrees F.

On pages 6 and 7 are given the most commonly required properties of saturated steam. The temperature of saturated steam depends upon the pressure under which it is generated, the temperature being the same as that of the water from which it is generated. When steam is generated in a closed vessel, the pressure increases with the increasing temperature of the water with which it is in contact, and from which it is generated.

The total heat in steam is made up of three quantities:

1. The heat required to raise the temperature of the water to the temperature of the steam.

2. The heat required to evaporate or

(Continued on page 20.)

COMPARISON OF THERMOMETER SCALES.

Centigrade.	Reaumur.	Fahrenheit.	Centigrade.	Reaumur.	Fahrenheit.	Centigrade.	Reaumur.	Fahrenheit.
–30	–24.0	–22.0	14	11.2	57.2	58	46.4	136.4
–28	–22.4	–18.4	16	12.8	60.8	60	48.0	140.0
–26	–20.8	–14.8	18	14.4	64.4	62	49.6	143.6
–24	–19.2	–11.2	20	16.0	68.0	64	51.2	147.2
–22	–17.6	–7.6	22	17.6	71.6	66	52.8	150.8
–20	–16.0	–4.0	24	19.2	75.2	68	54.4	154.4
–18	–14.4	–0.4	26	20.8	78.8	70	56.0	158.0
–16	–12.8	3.2	28	22.4	82.4	72	57.6	161.6
–14	–11.2	6.8	30	24.0	86.0	74	59.2	165.2
–12	–9.6	10.4	32	25.6	89.6	76	60.8	168.8
–10	–8.0	14.0	34	27.2	93.2	78	62.4	172.4
–8	–6.4	17.6	36	28.8	96.8	80	64.0	176.0
–6	–4.8	21.2	38	30.4	100.4	82	65.6	179.6
–4	–3.2	24.8	40	32.0	104.0	84	67.2	183.2
–2	–1.6	28.4	42	33.6	107.6	86	68.8	186.8
0	0.0	32.0	44	35.2	111.2	88	70.4	190.4
2	1.6	35.6	46	36.8	114.8	90	72.0	194.0
4	3.2	39.2	48	38.4	118.4	92	73.6	197.6
6	4.8	42.8	50	40.0	122.0	94	75.2	201.2
8	6.4	46.4	52	41.6	125.6	96	76.8	204.8
10	8.0	50.0	54	43.2	129.2	98	78.4	208.4
12	9.6	53.6	56	44.8	132.8	100	80.0	212.0

MACHINERY'S Data Sheet No. 21. Explanatory note: Page. 3.

Weight of Water per Cubic Foot and Heat Units in Water between 32° and 212° F.

Temperature, Degrees F.	Weight in pounds per Cubic Foot.	Heat Units.	Temperature, Degrees F.	Weight in Pounds per Cubic Foot,	Heat Units.	Temperature, Degrees F.	Weight in Pounds per Cubic Foot.	Heat Units.	Temperature, Degrees F.	Weight in Pounds per Cubic Foot.	Heat Units.
32	62.42	0.00	78	62.25	46.03	124	61.67	92.17	170	60.77	138.45
34	62.42	2.00	80	62.23	48.04	126	61.63	94.17	172	60.73	140.47
36	62.42	4.00	82	62.21	50.04	128	61.60	96.18	174	60.68	142.49
38	62.42	6.00	84	62.19	52.04	130	61.56	98.19	176	60.64	144.51
40	62.42	8.00	86	62.17	54.05	132	61.52	100.20	178	60.59	146.52
42	62.42	10.00	88	62.15	56.05	134	61.49	102.21	180	60.55	148.54
44	62.42	12.00	90	62.13	58.06	136	61.45	104.22	182	60.50	150.56
46	62.42	14.00	92	62.11	60.06	138	61.41	106.23	184	60.46	152.58
48	62.41	16.00	94	62.09	62.06	140	61.37	108.25	186	60.41	154.60
50	62.41	18.00	96	62.07	64.07	142	61.34	110.26	188	60.37	156.62
52	62.40	20.00	98	62.05	66.07	144	61.30	112.27	190	60.32	158.64
54	62.40	22.01	100	62.02	68.08	146	61.26	114.28	192	60.27	160.67
56	62.39	24.01	102	62.00	70.09	148	61.22	116.29	194	60.22	162.69
58	62.38	26.01	104	61.97	72.09	150	61.18	118.31	196	60.17	164.71
60	62.37	28.01	106	61.95	74.10	152	61.14	120.32	198	60.12	166.73
62	62.36	30.01	108	61.92	76.10	154	61.10	122.33	200	60.07	168.75
64	62.35	32.01	110	61.89	78.11	156	61.06	124.35	202	60.02	170.78
66	62.34	34.02	112	61.86	80.12	158	61.02	126.36	204	59.97	172.80
68	62.33	36.02	114	61.83	82.13	160	60.98	128.37	206	59.92	174.83
70	62.31	38.02	116	61.80	84.13	162	60.94	130.39	208	59.87	176.85
72	62.30	40.02	118	61.77	86.14	164	60.90	132.41	210	59.82	178.87
74	62.28	42.03	120	61.74	88.15	166	60.85	134.42	212	59.76	180.90
76	62.27	44.03	122	61.70	90.16	168	60.81	136.44			

PROPERTIES OF SATURATED STEAM.

Absolute Pressure.	Gage Pressure.	Temperature F.	Weight in Pounds per Cubic Foot of Steam.	Volume in Cubic Feet of One Pound of Steam.	Total Heat above 32° F.		Latent Heat, Heat Units.
					In the Water, Heat Units.	In the Steam, Heat Units.	
1	–27.9	102.1	.003	334.23	70.09	1113.1	1043.0
5	–19.7	162.3	.014	72.50	130.7	1131.4	1000.7
10	–9.6	193.2	.026	37.80	161.9	1140.9	979.0
14.7	0.	212.0	.038	26.36	180.9	1146.6	965.7
15	.3	213.0	.039	25.87	181.9	1146.9	965.0
20	5.3	227.9	.050	19.72	197.0	1151.5	954.4
25	10.3	240.0	.063	15.99	209.3	1155.1	945.8
30	15.3	250.2	.074	13.48	219.7	1158.3	938.9
35	20.3	259.2	.086	11.66	228.8	1161.0	932.2
40	25.3	267.1	.097	10.28	236.9	1163.4	926.5
45	30.3	274.3	.109	9.21	244.3	1165.6	921.3
50	35.3	280.9	.120	8.34	251.0	1167.6	916.6
55	40.3	286.9	.131	7.63	257.2	1169.4	912.3
60	45.3	292.5	.142	7.03	262.9	1171.2	908.2
65	50.3	297.8	.153	6.53	268.3	1172.8	904.5
70	55.3	302.7	.164	6.09	273.4	1174.3	900.9
75	60.3	307.4	.175	5.71	278.2	1175.7	897.5
80	65.3	311.8	.186	5.37	282.7	1177.0	894.3
85	70.3	316.0	.197	5.07	287.0	1178.3	891.3
90	75.3	320.0	.208	4.81	291.2	1179.6	888.4
95	80.3	323.9	.219	4.57	295.1	1180.7	885.6
100	85.3	327.6	.230	4.36	298.9	1181.8	882.9
110	95.3	334.5	.251	3.98	306.1	1184.0	877.9
120	105.3	341.0	.272	3.67	312.8	1185.9	873.2
130	115.3	347.1	.294	3.41	319.1	1187.8	868.7
140	125.3	352.8	.315	3.18	325.0	1189.5	864.6
150	135.3	358.2	.336	2.98	330.6	1191.2	860.6
160	145.3	363.3	.357	2.80	335.9	1192.7	856.9

MACHINERY'S Data Sheet No. 21. Explanatory note: Page. 3.

PROPERTIES OF SATURATED STEAM (Continued).

Absolute Pressure.	Gage Pressure.	Temperature F.	Weight in Pounds per Cubic Foot of Steam.	Volume in Cubic Feet of One Pound of Steam.	Total Heat above 32° F. In the Water, Heat Units.	Total Heat above 32° F. In the Steam, Heat Units.	Latent Heat, Heat Units.
170	155.3	368.2	.378	2.65	340.9	1194.2	853.3
180	165.3	372.8	.398	2.51	345.8	1195.7	849.9
190	175.3	377.3	.419	2.39	350.4	1197.0	846.6
200	185.3	381.6	.440	2.27	354.9	1198.3	843.4
210	195.3	385.7	.461	2.17	359.2	1199.6	840.4
220	205.3	389.7	.485	2.06	362.2	1200.8	838.6
230	215.3	393.6	.506	1.98	366.2	1202.0	835.8
240	225.3	397.3	.527	1.90	370.0	1203.1	833.1
250	235.3	400.9	.548	1.83	373.8	1204.2	830.5
260	245.3	404.4	.569	1.76	377.4	1205.3	827.9
270	255.3	407.8	.589	1.70	380.9	1206.3	825.4
280	265.3	411.0	.610	1.64	384.3	1207.3	823.0
290	275.3	414.2	.630	1.585	387.7	1208.3	820.6
300	285.3	417.4	.651	1.535	390.9	1209.2	818.3
350	335.3	432.0	.755	1.325	406.3	1213.7	807.5
400	385.3	444.9	.857	1.167	419.8	1217.7	797.9
450	435.3	456.6	.959	1.042	432.2	1221.3	789.1
500	485.3	467.4	1.062	.942	443.5	1224.5	781.0
550	535.3	477.5	1.164	.859	454.1	1227.6	773.5
600	585.3	486.9	1.266	.790	464.2	1230.5	766.3
650	635.3	495.7	1.368	.731	473.6	1233.2	759.6
700	685.3	504.1	1.470	.680	482.4	1235.7	753.3
750	735.3	512.1	1.572	.636	490.9	1238.0	747.2
800	785.3	519.6	1.674	.597	498.9	1240.3	741.4
850	835.3	526.8	1.776	.563	506.7	1242.5	735.8
900	885.3	533.7	1.878	.532	514.0	1244.7	730.6
950	935.3	540.3	1.980	.505	521.3	1246.7	725.4
1000	985.3	546.8	2.082	.480	528.3	1248.7	720.3

STEAM PIPE SIZES—I

Table I—Flow of Steam in Pounds per Minute through Pipes 100 feet in Length.

Diameter of Pipe	Drop in Pressure (Pounds) in 100 feet Length of Pipe.								
	1/4	1/2	3/4	1	1 1/2	2	3	4	5
1	0.44	0.63	0.78	0.91	1.1	1.3	1.7	2.0	2.3
1 1/4	0.81	1.2	1.4	1.7	2.1	2.4	3.0	3.6	4.1
1 1/2	1.6	1.9	2.3	2.7	3.4	3.9	4.9	5.9	6.8
2	2.9	4.2	5.2	5.9	7.4	8.6	10.9	13.0	14.9
2 1/2	5.3	7.5	9.3	10.8	13.4	15.6	19.7	23.4	26.9
3	8.6	12.3	15.2	17.6	21.8	25.4	32.0	31.8	43.7
3 1/2	12.9	18.3	22.6	26.3	32.5	37.9	47.8	56.9	65.3
4	18.1	25.7	31.8	36.9	45.8	53.3	67.2	80.1	91.9
5	32.2	45.7	56.6	65.7	81.3	94.7	120.0	142.0	163.0
6	51.7	73.3	90.9	106	131	152	192	229	262
7	76.7	109	135	157	194	226	285	339	390
8	108	154	190	222	274	319	402	478	549
9	147	209	258	299	371	432	545	649	745
10	192	273	339	393	487	567	715	852	977
12	305	434	537	623	771	899	1130	1350	1550
15	535	761	942	1090	1350	1580	1990	2370	2720

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STEAM PIPE SIZES—II

Table II– Factors with which to multiply the figures obtained in Table I, for initial pressures over 10 pounds, to obtain the flow of steam in pounds per minute through pipes 100 ft. in length.

Drop in Pressure, (Pounds)	Initial Pressure (Pounds).					
	10	20	30	40	60	80
1/4	1.27	1.49	1.68	1.84	2.13	2.38
1/2	1.26	1.48	1.66	1.83	2.11	2.36
1	1.24	1.46	1.64	1.80	2.08	2.32
2	1.21	1.41	1.59	1.75	2.02	2.26
3	1.17	1.37	1.55	1.70	1.97	2.20
4	1.14	1.34	1.51	1.66	1.92	2.14
5	1.12	1.31	1.47	1.62	1.87	2.09

Table III– Factors with which to multiply the figures obtained in Table I, for length of pipe smaller or greater than 100 feet, to obtain the flow of steam in pounds per minute.

Feet	Factor	Feet	Factor	Feet	Factor	Feet	Factor
10	3.16	120	0.91	275	0.60	600	0.40
20	2.24	130	0.87	300	0.57	650	0.39
30	1.82	140	0.84	325	0.55	700	0.37
40	1.58	150	0.81	350	0.53	750	0.36
50	1.41	160	0.79	375	0.51	800	0.35
60	1.29	170	0.76	400	0.50	850	0.34
70	1.20	180	0.74	425	0.48	900	0.33
80	1.12	190	0.72	450	0.47	950	0.32
90	1.05	200	0.70	475	0.46	1000	0.31
100	1.00	225	0.66	500	0.45		
110	0.95	250	0.63	550	0.42		

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STEAM PIPE SIZES—III

D'Arcy's formulas for flow of steam in pipes, used for calculating Table I.

$$Q = c\sqrt{\frac{(P-P_1)\,d^5}{w\,L}}, \qquad W = c\sqrt{\frac{w\,(P-P_1)\,d^5}{L}},$$

$$d = \sqrt[5]{\frac{W^2 L}{c^2 w (P-P_1)}}, \qquad P-P_1 = \frac{Q^2\,w\,L}{c^2\,d^5},$$

Q = Cubic feet of steam per minute,

W = Pounds of steam per minute,

w = Weight per cubic foot of steam at pressure P_1

P = Initial pressure,

P_1 = Terminal pressure,

$P-P_1$ = Drop in pressure,

d = Diameter of pipe in inches,

L = Length of pipe, in feet,

c = Constant.

Table IV.

Diameter of Pipe, Inches.	Value of Constant C.	5th. Power of d.
1	45.3	1
1½	48.5	6
2	52.7	32
2½	54.3	97
3	56.1	243
3½	57.1	523
4	57.8	1024
5	58.4	3125
6	59.5	7776
7	60.1	16807
8	60.7	32768
9	61.2	59049
10	61.8	100000

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STEAM PIPE SIZES—IV

Table V.

Diameter of Pipe in Inches	Direct Radiation. Based on an efficiency of 300 heat units per square foot of radiating surface per hour, and a drop in pressure of ¼ pound in 100 ft. length of pipe. Square feet of direct radiation.	Indirect Radiation. Based on an efficiency of 600 heat units per square foot of radiation per hour and a drop in pressure of ¼ pound in 100 ft. length of pipe. Square feet of indirect radiation.
1	60	40
1¼	100	72
1½	135	95
2	370	260
2½	670	475
3	1080	775
3½	1625	1160
4	2280	1620
5	4060	2900
6	6520	4660
7	9660	6900
8	13600	9720

Table VI.

Single Pipe Risers. Based on velocities of 10 and 15 feet per second.

Diam. of Riser	Square feet of direct radiation, 10 feet per sec., velocity	Square feet of direct radiation, 15 feet per sec., velocity
1	30	50
1¼	60	90
1½	80	120
2	130	200
2½	190	290
3	290	340
3½	390	590

Table VII.

Return Pipes.

Steam Pipe	Dry Return	Sealed Return
1	1	¾
1¼	1	1
1½	1¼	1
2	1½	1¼
2½	2	1½
3	2½	2
3½	2½	2
4	3	2½
5	3	2½
6	3½	3
7	3½	3
8	4	3½
9	5	3½
10	5	4

Contributed by Chas. L. Hubbard, MACHINERY'S Data Sheet No. 109. Explanatory note: Page 32.

WEIGHT OF STEAM DISCHARGED BY SAFETY VALVES

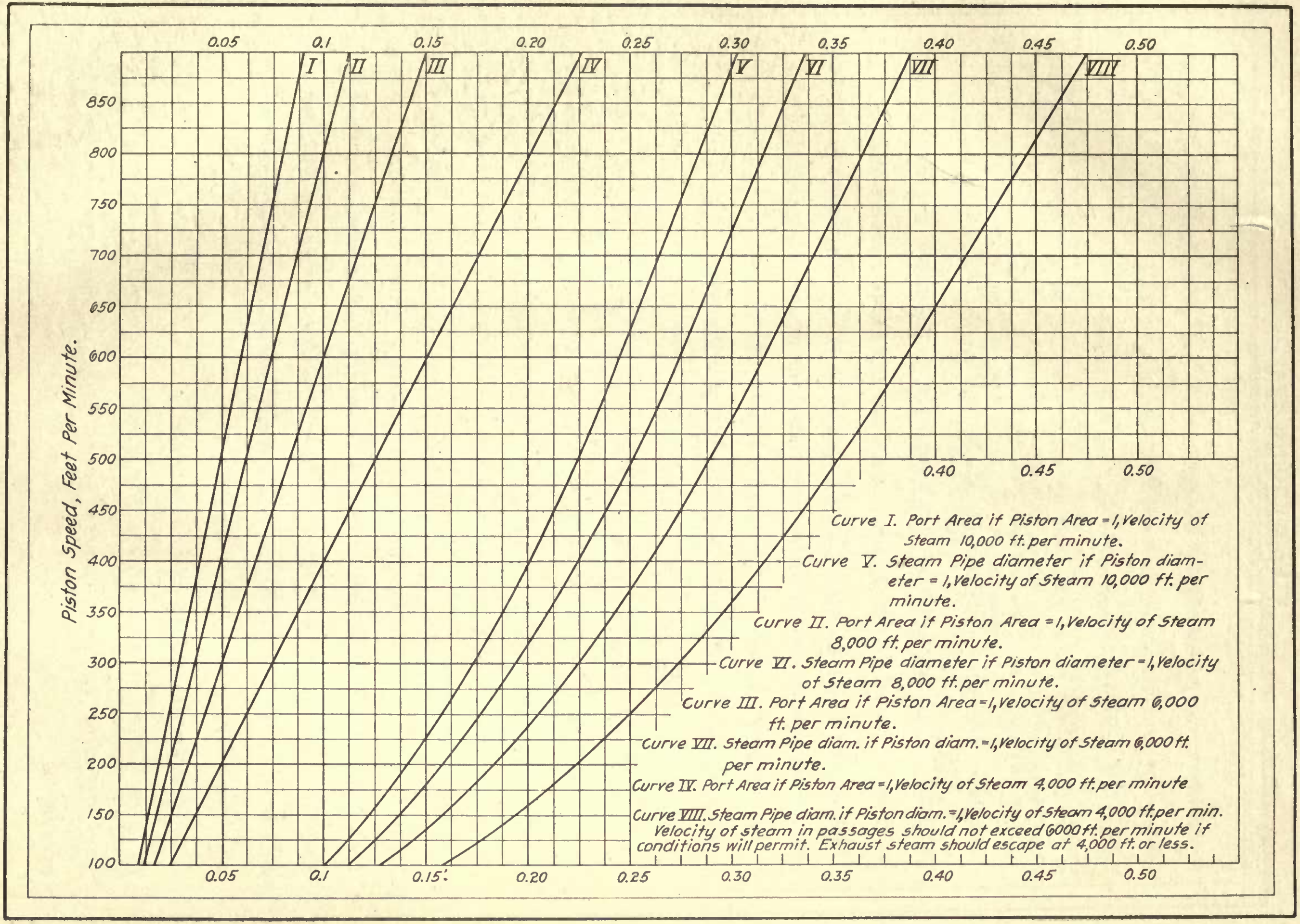
Diameter of Safety Valve, Inches	Discharge Area, Square Inches	Steam discharged per hour, in Pounds					
		Gage Pressure					
		100	125	150	175	200	250
		Absolute Pressure					
		115	140	165	190	215	265
1	0.22	1100	1340	1580	1670	1910	2530
1½	0.33	1650	2010	2370	2510	2870	3795
2	0.44	2200	2680	3150	3350	3825	5060
2½	0.55	2750	3350	3940	4180	4780	6325
3	0.66	3300	4020	4730	5020	5740	7590
3½	0.77	3850	4685	5520	5850	6695	8855
4	0.88	4400	5350	6310	6690	7650	10120
4½	0.99	4950	6020	7100	7530	8610	11385
5	1.10	5500	6690	7890	8365	9565	12650
6	1.32	6600	8030	9460	10040	11075	15180
7	1.54	7700	9370	11040	11710	13390	17710
8	1.76	8800	10700	12620	13385	15305	20240
9	1.98	9900	12050	14200	15060	17215	22770
10	2.20	11000	13390	15770	16730	19130	25300

The table above has been calculated for valve lift of 0.1 inch. If the lift is changed, the values given above should be multiplied by the factors below:

Valve Lift	Factor	Valve Lift	Factor
1/16	0.62	7/64	1.09
5/64	0.78	1/8	1.25
3/32	0.94	5/32	1.56

Contributed by H. O. Kieferstein. Explanatory note: Page 32.

DIAMETERS OF STEAM PIPES AND AREAS OF STEAM PORTS



Contributed by H. O. Kieferstein. Explanatory note: Page 32,

STEAM ENGINE DESIGN—I

Cylinder:— In proportioning the cylinder for any given power of engine the following data is usually furnished the designer: boiler pressure, back pressure, cut-off, clearance and piston speed.

First, find the mean effective pressure (M.E.P.) for the given conditions by the formula $M.E.P. = \frac{0.9P(1+2.3 \log R)}{R} - 0.9p$, in which

P = boiler pressure (absolute), R = "actual" ratio of expansion = $\frac{1 + \text{clearance}}{\text{clearance} + \text{cut-off}}$, in which the clearance and cut-off are expressed as a percentage of the stroke, p = back pressure (absolute).

Area of Piston:— $A = \frac{33000\ H.P.}{M.E.P. \times \text{piston speed}}$, in which A = area of piston in square inches. The diameter is usually made even inches and the piston speed changed to give the same H.P. This is done by the following equation: $\frac{\text{First piston speed} \times \text{first piston area}}{\text{new piston area}}$ = new piston speed.

In calculating the effective piston area we must allow for the area of the piston rod upon one side of the piston: $A_1 = \frac{2A - a}{2}$, in which A_1 = effective area of piston, A = actual area of piston, a = area of piston rod. After assuming a piston diameter of even inches we must substitute its "effective" area in the equation for finding the new piston speed.

Thickness of Cylinder Shell:— $t = 0.0003\,pd + 0.8$, in which t = thickness of shell in inches, d = diameter of cylinder in inches, p = boiler pressure per square inch. The thickness of flanges may be made 1.3t; the metal of the steam chest and passages 0.8t; and the valve seat about 1.25t.

Counterbore:— Depth of counterbore shoulder $\frac{3}{16}$ inch in cylinders 12 to 16 inches in diameter. The length should be such that $\frac{1}{3}$ of packing ring of piston passes over edge of counterbore at end of stroke.

STEAM ENGINE DESIGN—II

Cylinder Heads :– The thickness may be 1.25t (see sheet I), with stiffening ribs depending on diameter.

Cylinder Head Bolts :– $n = 0.705\,d_1 + 2.18$, in which n = number of bolts, d_1 = diameter of counterbore. The size of bolts should be such that the total load due to steam pressure and "screwing up" shall not exceed 7000 pounds per square inch, for mild steel.

Total pressure on head $= p\left(\frac{\pi d_1^2}{4}\right)$, in which p = boiler pressure per square inch, d_1 = diameter of counterbore. The pressure due to screwing up may be taken as 2500 pounds upon each stud.

Diameter of Bolt Circle :– $D_1 = d_1 + 2t + d$, in which D_1 = diameter of bolt circle, d_1 = diameter of counterbore, t = thickness of cylinder wall; d = diameter of bolts. Diameter of cylinder head $= D_1 + 2d + \frac{1}{4}$ inch.

Area of Ports :– These are based on the velocity of steam flow through them, as follows :– Steam Ports 8000 feet per minute, Exhaust Ports 6000 feet per minute.

Piston :– For horizontal engines the thickness of piston may be found by the formula $T = \sqrt[4]{L \times D}$ in which T = thickness of piston in inches, L = length of stroke in inches, D = diameter of piston in inches.

Piston Rod :– The area of metal through the weakest part is found by the formula $a = \frac{\pi}{2f} \times D^2 \times p$, in which a = area of metal in weakest part of rod, f = 10000 for wrought iron, and 13000 for steel, D = diameter of piston in inches, p = difference in pressure per square inch acting upon the two sides of the piston.

Stiffness of Piston Rod :– The required size of the body of the piston rod may be determined by the formula $d = K \times D \times \sqrt{p}$, in which d = diameter of rod, K = 0.0169 to 0.0182 for short stroke engines, and 0.02 to 0.0224 for moderately long stroke horizontal engines, p = difference in pressure per square inch acting upon the two sides of piston.

Contributed by Chas. L. Hubbard, MACHINERY's Data Sheet No. 120. Explanatory note: Page 38.

STEAM ENGINE DESIGN—III

Connecting Rod:— The connecting rod is commonly made from two to four times the length of stroke. Two and one-half to three is an average. For round rods the diameter at the center may be taken as $d = a\sqrt{DL\sqrt{p}} + C$, in which d = diameter of rod in inches, D = diameter of cylinder in inches, L = length of rod in feet, p = boiler pressure per square inch, a = 0.15 for high speed, and 0.18 for moderate speed, $C = \frac{1}{2}$ inch for high speed, and $\frac{3}{4}$ inch for moderate speed.

The diameter at the necks may be made about 1.1 times that of the piston rod. In high speed engines the connecting rod is commonly made rectangular in section, and tapered from the cross-head to the crank end to overcome the stresses due to the inertia of the rod. In this case the thickness of the rod (t) may be computed by the formula $t = 0.0209\sqrt{DL\sqrt{p}} + 0.47$ in which D, L, and p represent the same quantities as before.

Having found the value of t, make the depth at the cross-head $1.5t$, and at the crank pin $2.25t$.

Crank Pin:— This should be designed with sufficient bearing surface to prevent heating, and then checked for strength and rigidity. For the first condition we have $l = \frac{0.06 \text{ H.P.}}{L}$, in which l = length of pin in inches, L = length of stroke in feet, $d = \frac{A \times \text{M.E.P.}}{500\,l}$, in which d = diameter of pin in inches, A = area of piston in square inches, M.E.P. = mean effective pressure, l = length of pin in inches. The pin may be checked for strength as follows, in which the value of d should not exceed that found above, $d = \sqrt[3]{\frac{5.1\,Pl}{12000}}$, in which d = diameter of pin in inches, P = total boiler pressure on piston in pounds, l = length of pin in inches.

Crank Arm:— Diameter of hub = $1.8D$ to $2D$, diameter of eye = $2d$ to $2.25d$, length of hub = $1D$ to $1.2D$, length of eye = $1.25d$ to $1.5d$, in which D = diameter of shaft, and d = diameter of crank pin. The thickness of web is made from 0.5 to 0.6 of the length of hub or eye with which it connects. In the case of cast iron, stiffening webs, the full depth of hub and eye, should be provided.

Contributed by Chas. L. Hubbard, MACHINERY'S Data Sheet No. 120. Explanatory note: Page 38.

STEAM ENGINE DESIGN—IV

Valve Stem :- $d = \sqrt{\frac{lbp}{F}}$, in which d = diameter of rod in inches, l = length of valve in inches, b = width of valve in inches, p = pressure per square inch on valve, F = 12000 for long steel rods; and 14500 for short steel rods.

Cross Head :- The pressure on the guides may be taken as 40 to 60 pounds per square inch for ordinary lubrication, and 80 to 100 pounds with good lubrication. $W = Ap \tan a$, in which W = total pressure on guides in pounds, A = area of piston in square inches, p = pressure on piston in pounds per square inch, a = the angle between the connecting rod and the center line of piston rod extended, when connecting rod and crank are at right angles.

Wrist Pin :- $d = 0.03\sqrt{mP}$, in which d = diameter of pin in inches, m = factor varying from 1.25 to 1.5, P = total pressure on piston in pounds. The length of pin may equal d.

Fly Wheel :- $W = \frac{C}{DR^2}$, in which W = weight of rim per H.P., D = diameter of rim in feet, R = revolutions per minute, C = 5,500,000 for electric light engines, 5,000,000 for mill engines, 4,000,000 for ordinary engines. The width of rim is determined by required width of belt, from which the thickness may be found by $t = \frac{W}{0.26\,CB}$, in which t = thickness of rim in inches, W = total weight of rim in pounds, C = circumference of rim in inches, B = width of rim.

The thickness of the arms is found by the formula $b = \frac{UL}{30h^2}$, in which b = thickness of arm in inches, h = width of arm at hub in inches, L = length of arm in feet, U = load carried by one arm = total effective belt tension divided by one-half the number of arms. The value of h is assumed, and b is found by the formula given.

VOLUME OF CYLINDERS, IN CUBIC FEET.

Diameter, inches.	Stroke in Inches. 4	4½	5	5½	6	6½	7	7½	8	9	10	11
3	.0163	.0184	.0204	.0225	.0245	......	......	......	......	......	......	......
3½	.0224	.0251	.0278	.0306	.0334	.0362	......	......	......	......	......	......
4	......	......	.0363	.0400	.0436	.0472	.0508	.0544	......	......	......	......
4½	......	......	......	.0506	.0552	.0598	.0644	.0690	.0736	......	......	......
5	......	......	......	......	.0681	.0738	.0795	.0851	.0909	.1022	.1135	......
5½	......	......	......	......	......	.0893	.0961	.1032	.1100	.1236	.1374	.1512
6	......	......	......	......	......	......	.1145	.1227	.1308	.1472	.1635	.1800
6½	......	......	......	......	......	......	......	.1440	.1535	.1726	.1917	.2120
7	......	......	......	......	......	......	......	......	.1781	.201	.225	.245
7½	......	......	......	......	......	......	......	......	......	.230	.2555	.2817
8	......	......	......	......	......	......	......	......	......	......	.291	.320
9	......	......	......	......	......	......	......	......	......	......	......	......
10	......	......	......	......	......	......	......	......	......	......	......	......
11	......	......	......	......	......	......	......	......	......	......	......	......
12	......	......	......	......	......	......	......	......	......	......	......	......
13	......	......	......	......	......	......	......	......	......	......	......	......
14	......	......	......	......	......	......	......	......	......	......	......	......
15	......	......	......	......	......	......	......	......	......	......	......	......
16	......	......	......	......	......	......	......	......	......	......	......	......
17	......	......	......	......	......	......	......	......	......	......	......	......
17½	......	......	......	......	......	......	......	......	......	......	......	......
18	......	......	......	......	......	......	......	......	......	......	......	......
18½	......	......	......	......	......	......	......	......	......	......	......	......

Diameter, inches.	Stroke in Inches. 12	13	14	16	18	20	22	24	26	28	30
3	......	......	......	......	......	......	......	......	......	......	......
3½	......	......	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	......	......	......
4½	......	......	......	......	......	......	......	......	......	......	......
5	......	......	......	......	......	......	......	......	......	......	......
5½	......	......	......	......	......	......	......	......	......	......	......
6	.1963	......	......	......	......	......	......	......	......	......	......
6½	.2300	.2490	......	......	......	......	......	......	......	......	......
7	.264	.2895	.314	......	......	......	......	......	......	......	......
7½	.3061	.3320	.358	.408	......	......	......	......	......	......	......
8	.349	.378	.406	.465	......	......	......	......	......	......	......
9	.442	.479	.516	.589	.662	......	......	......	......	......	......
10	.545	.591	.636	.727	.818	.910	......	......	......	......	......
11	......	......	.769	.879	.989	1.10	1.21	......	......	......	......
12	......	......	......	1.045	1.175	1.31	1.44	......	......	......	......
13	......	......	......	1.228	1.382	1.535	1.688	......	......	......	......
14	......	......	......	1.425	1.603	1.781	1.959	2.137	2.320	......	......
15	......	......	......	......	1.842	2.045	2.25	2.455	2.655	......	......
16	......	......	......	......	2.092	2.325	2.560	2.795	3.025	......	......
17	......	......	......	......	......	2.625	2.89	3.15	3.42	3.685	......
17½	......	......	......	......	......	2.78	3.06	3.34	3.62	3.89	......
18	......	......	......	......	......	2 94	3.24	3.535	3 83	4.13	4.42
18½	......	......	......	......	......	3.111	3.425	3.735	4.045	4.35	4.67

Contributed by B. J. Sinne, MACHINERY'S Data Sheet No. 12 (Railway Edition).
Explanatory note: Page 38.

VOLUME OF CYLINDERS, IN CUBIC FEET (Continued).

Diameter, Inches.	Stroke, in Inches. 16	18	20	22	24	26	28	30	32	34	36	38
19	2.625	2.953	3.28	3.61	3.935	4.27	4.59	4.92	5.24	...	...	...
19½	2.76	3.11	3.45	3.8	4.15	4.5	4.84	5.18	5.525	5.870	...	...
20	2.90	3.27	3.63	4.0	4.36	4.72	5.08	5.44	5.80	6.16	...	...
20½	...	3.44	3.82	4.21	4.59	4.97	5.35	5.73	6.11	6.49	...	...
21	...	3.61	4.00	4.41	4.81	5.21	5.61	6.01	6.41	6.81	7.21	...
21½	...	3.78	4.20	4.62	5.04	5.46	5.88	6.30	6.72	7.14	7.56	...
22	...	3.96	4.39	4.84	5.28	5.72	6.16	6.60	7.04	7.48	7.92	...
22½	...	...	46.02	5.06	5.52	5.98	6.44	6.90	7.36	7.82	8.28	...
23	...	...	48.08	5.29	5.76	6.24	6.72	7.20	7.68	8.16	8.64	...
23½	...	...	50.20	5.52	6.01	6.51	7.01	7.51	8.01	8.51	9.01	9.51
24	...	...	...	5.76	6.28	6.80	7.32	7.84	8.36	8.88	9.40	9.92
25	...	...	...	6.25	6.80	7.37	7.94	8.51	9.08	9.65	10.22	10.79
26	...	...	...	6.76	7.37	7.98	8.59	9.20	9.81	10.42	11.03	11.64
27	...	...	...	7.29	7.95	8.61	9.27	9.93	10.59	11.25	11.91	12.57
28	...	...	...	7.84	8.55	9.26	9.98	10.69	11.40	12.11	12.82	13.54
29	...	...	...	8.41	9.17	9.93	10.70	11.46	12.23	12.99	13.76	14.52
30	...	...	...	8.90	9.81	10.63	11.45	12.27	13.09	13.91	14.73	15.55
31	...	...	...	...	10.48	11.36	12.23	13.10	13.97	14.86	15.73	16.59
32	...	...	...	...	...	12.11	13.04	13.97	14.90	15.83	16.76	17.69
33	...	...	...	...	...	12.88	13.87	14.86	15.85	16.84	17.83	18.82
34	...	...	...	...	...	13.66	14.71	15.76	16.81	17.86	18.91	19.96
35	...	...	...	...	...	...	...	16.70	17.81	18.93	20.04	21.15
36	...	...	...	...	...	...	...	17.67	18.84	20.02	21.20	22.38

Explanatory note: Page 38.

transform water at that temperature into steam, this heat quantity being termed the internal latent heat.

3. The heat corresponding to the external work done by the steam in making room for itself against the pressure of the atmosphere, or against the surrounding steam, if enclosed in a vessel. The sum of the two last quantities is called the latent heat of steam.

Referring to the tables on pages 6 and 7 it will be seen that these tables give the temperature of the steam for various pressures, the weight in pounds per cubic foot of steam at given pressures, the volume in cubic feet of one pound of steam at a given pressure, and the heat units in the water and in the steam, together with the latent heat in the steam. These tables will be found convenient in calculations relating to steam and steam engines.

Assume as an example that it is required to find the various properties of saturated steam for 115.3 pounds gage pressure. Referring to the table on page 6 we find that steam at this pressure has a temperature of 347.1 degrees F., that it weighs 0.294 pound per cubic foot, and that the volume of one pound of the steam is 3.41 cubic feet. The total number of heat units in the water is 319.1, and in the steam 1,187.8, the number of latent heat units in the steam being 868.7.

Steam Pipe Sizes

The problem of determining the size required for steam pipes under varying conditions is one which often confronts the engineer, and the difficulty of obtaining reliable data is well known. In order to facilitate work of this character, the tables given on pages 8 to 11, inclusive, have been computed. Tables I, II and III (pages 8 and 9) are computed from D'Arcy's formulas for flow of steam in pipes, which are given on page 10. Table IV gives the values of the constants used in these formulas for various diameters of pipe.

Table I, on page 8, gives the flow of steam in pounds per minute through pipes 100 feet in length, for initial pressures of ¼ to 5 pounds, assuming that the pressure in each case drops to zero; that is, the drop in pressure equals the initial pressure. It is seen from the table, for example, that a 2-inch pipe will discharge 2.9 pounds of steam per minute under a pressure of ¼ pound per square inch, or 14.9 pounds under a pressure of 5 pounds, the terminal pressure dropping to zero in each case. The table is sufficiently accurate for any initial pressure less than 10 pounds for the drops in pressure noted at the heads of the columns, regardless of whether the pressure falls to zero or not. For example, a 4-inch pipe, 100 feet long, will discharge approximately 18.1 pounds of steam per minute with a drop in pressure of ¼ pound, or 91.9 pounds with a drop of 5 pounds, for any initial pressure up to 10 pounds.

As the initial pressure increases, the quantity of steam discharged for a given drop in pressure becomes greater than given in Table I. Table II, page 9, gives correction factors for higher initial pressures. For example: The factor for a drop of 5 pounds at an initial pressure of 80 pounds is 2.09, so that under these conditions a 4-inch pipe will discharge $91.9 \times 2.09 = 192$ pounds of steam per minute, the value 91.9 having been obtained from Table I.

The figures given in Table I are for pipe runs of 100 feet only. For different lengths, the results should be corrected by the factors given in Table III, page 9. For example: A 4-inch pipe, 100 feet in length, will discharge 91.9 pounds of steam per minute with a drop in pressure of 5 pounds at the discharge end; if the pipe is only 50 feet in length, it will discharge $91.9 \times 1.41 = 129.5$ pounds, or if it is 500 feet in length, it will discharge $91.9 \times 0.45 = 41.4$ pounds.

(Continued on page 32.)

DIMENSIONS OF PISTON RINGS

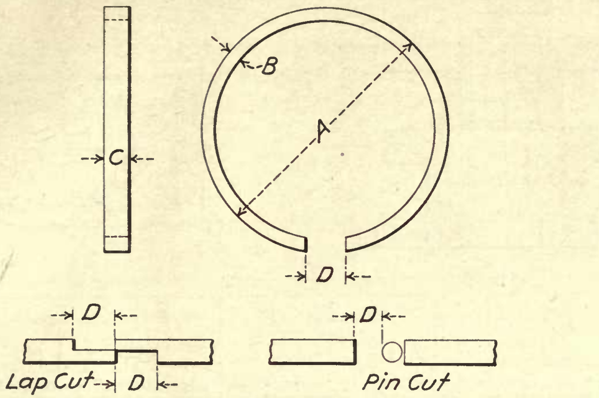


Table of Dimensions for Equal Section Rings

Dimensions	Diameter of Cylinder in Inches														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	6 5/32	7 5/32	8 3/16	9 3/16	10 7/32	11 1/4	12 1/4	13 9/32	14 9/32	15 5/16	16 11/32	17 11/32	18 3/8	19 13/32	20 13/32
B	1/4	9/32	5/16	3/8	13/32	7/16	15/32	1/2	9/16	19/32	5/8	11/16	3/4	3/4	13/16
C	5/16	3/8	3/8	7/16	7/16	1/2	1/2	9/16	9/16	11/16	11/16	3/4	3/4	13/16	13/16
D	35/64	39/64	21/32	23/32	25/32	27/32	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 9/32	1 11/32

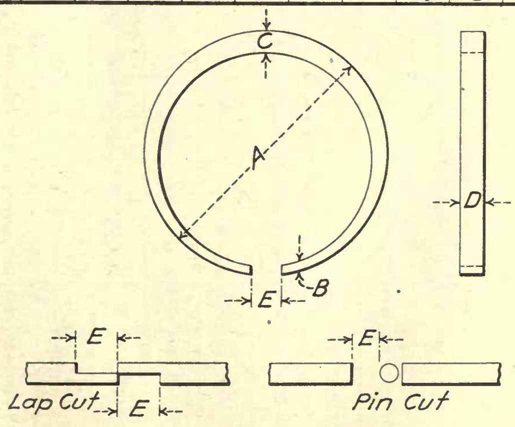
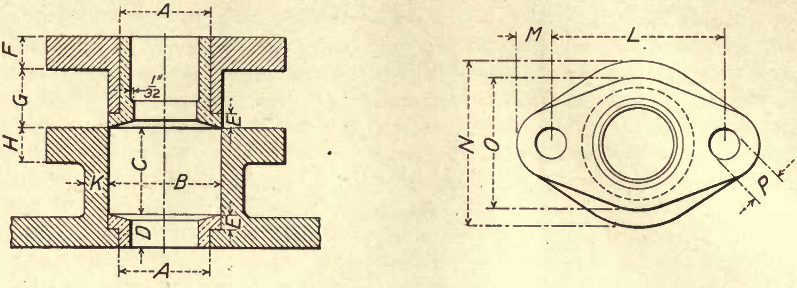


Table of Dimensions for Eccentric Rings

Dimensions	Diameter of Cylinder in Inches														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	6 5/32	7 5/32	8 3/16	9 3/16	10 7/32	11 1/4	12 1/4	13 9/32	14 9/32	15 5/16	16 11/32	17 11/32	18 3/8	19 13/32	20 13/32
B	3/16	7/32	1/4	9/32	9/32	5/16	11/32	3/8	13/32	7/16	15/32	15/32	1/2	17/32	9/16
C	9/32	5/16	11/32	3/8	13/32	7/16	15/32	1/2	9/16	5/8	11/16	11/16	3/4	13/16	7/8
D	5/16	3/8	3/8	7/16	7/16	1/2	1/2	9/16	9/16	11/16	11/16	3/4	3/4	13/16	13/16
E	35/64	39/64	21/32	23/32	25/32	27/32	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 9/32	1 11/32

Contributed by C. R. McGahey. Explanatory note: Page 38.

DIMENSIONS OF STUFFING BOXES AND GLANDS



Diam. of Rod	A	B	C		D	E	F		G	H	K	L	M	N	O	P
			High Press.	Low Press.			Cast Iron	Brass								
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1/2	3/4	1	1 1/2	1 1/8	7/16	3/16		3/8	3/4	7/16	5/16	1 13/16	7/16	1 3/4	1 5/16	3/8
9/16	13/16	1 1/16	1 1/2	1 1/8	7/16	3/16		3/8	3/4	7/16	5/16	1 13/16	7/16	1 7/8	1 5/16	3/8
5/8	7/8	1 1/8	1 1/2	1 1/8	7/16	3/16		3/8	3/4	7/16	5/16	1 15/16	7/16	1 7/8	1 7/16	3/8
11/16	15/16	1 3/16	1 1/2	1 1/8	7/16	3/16		3/8	3/4	7/16	5/16	1 15/16	7/16	2	1 7/16	3/8
3/4	1 1/16	1 3/8	1 7/8	1 1/4	9/16	1/4		3/8	7/8	1/2	3/8	2 5/16	1/2	2 1/4	1 3/4	7/16
13/16	1 1/8	1 7/16	1 7/8	1 1/4	9/16	1/4		3/8	7/8	1/2	3/8	2 5/16	1/2	2 3/8	1 3/4	7/16
7/8	1 3/16	1 1/2	1 7/8	1 1/4	9/16	1/4		3/8	7/8	1/2	3/8	2 7/16	1/2	2 3/8	1 7/8	7/16
15/16	1 1/4	1 9/16	1 7/8	1 1/4	9/16	1/4		3/8	7/8	1/2	3/8	2 7/16	1/2	2 1/2	1 7/8	7/16
1	1 5/16	1 3/4	2 1/4	1 1/2	11/16	5/16		7/16	1 1/8	5/8	7/16	2 3/4	9/16	2 3/4	2	1/2
1 1/8	1 7/16	1 7/8	2 1/4	1 1/2	11/16	5/16		7/16	1 1/8	5/8	7/16	2 7/8	9/16	2 7/8	2 1/8	1/2
1 1/4	1 5/8	2	2 1/4	1 1/2	11/16	5/16		7/16	1 1/8	5/8	7/16	3	9/16	3	2 1/4	1/2
1 3/8	1 3/4	2 1/4	2 5/8	1 3/4	3/4	5/16	5/8	9/16	1 1/4	3/4	1/2	3 1/2	3/4	3 3/8	2 5/8	5/8
1 1/2	1 7/8	2 3/8	2 5/8	1 3/4	3/4	5/16	5/8	9/16	1 1/4	3/4	1/2	3 5/8	3/4	3 1/2	2 3/4	5/8
1 5/8	2	2 1/2	2 5/8	1 3/4	3/4	5/16	5/8	9/16	1 1/4	3/4	1/2	3 3/4	3/4	3 5/8	2 7/8	5/8
1 3/4	2 1/8	2 3/4	3	2	7/8	3/8	3/4	9/16	1 1/2	7/8	5/8	4 1/4	7/8	4 1/8	3 1/8	3/4
1 7/8	2 1/4	2 7/8	3	2	7/8	3/8	3/4	9/16	1 1/2	7/8	5/8	4 3/8	7/8	4 1/4	3 1/4	3/4
2	2 3/8	3	3	2	7/8	3/8	3/4	9/16	1 1/2	7/8	5/8	4 1/2	7/8	4 3/8	3 3/8	3/4
2 1/8	2 1/2	3 1/8	3	2	7/8	3/8	3/4	9/16	1 1/2	7/8	5/8	4 5/8	7/8	4 1/2	3 1/2	3/4
2 1/4	2 5/8	3 3/8	3 3/8	2 1/4	1	7/16	7/8	5/8	1 5/8	1	3/4	5 1/8	1	5	3 3/4	7/8
2 3/8	2 3/4	3 1/2	3 3/8	2 1/4	1	7/16	7/8	5/8	1 5/8	1	3/4	5 1/4	1	5 1/8	3 7/8	7/8
2 1/2	2 7/8	3 5/8	3 3/8	2 1/4	1	7/16	7/8	5/8	1 5/8	1	3/4	5 3/8	1	5 1/4	4	7/8

United States Navy Standard, MACHINERY'S Data Sheet No. 115. Explanatory note: Page. 38.

PITCH OF BOLTS IN WATER AND STEAM JOINTS

Thickness of Flange for Through Bolts = $1\frac{1}{4}$ to $1\frac{1}{2}$ Bolt Diameters
Thickness of Flange for Through Studs = $1\frac{1}{2}$ to 2 Stud Diameters
Width of Flange = $2\frac{3}{4}$ to $3\frac{1}{2}$ Bolt or Stud Diameters

Diameter of Bolt, Inches	50 lbs. and under 7 diam. Inches	50 to 90 lbs. 6 diam. Inches	90 to 125 lbs. $5\frac{1}{4}$ diam. Inches	125 to 150 lbs. $4\frac{1}{2}$ diam. Inches	150 to 175 lbs. 4 diam. Inches	175 to 200 lbs. $3\frac{1}{2}$ diam. Inches
$\frac{1}{2}$	$3\frac{1}{2}$	3	$2\frac{5}{8}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$
$\frac{5}{8}$	$4\frac{3}{8}$	$3\frac{3}{4}$	$3\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$
$\frac{3}{4}$	$5\frac{1}{4}$	$4\frac{1}{2}$	4	$3\frac{1}{2}$	3	$2\frac{3}{4}$
$\frac{7}{8}$	$6\frac{1}{8}$	$5\frac{1}{4}$	$4\frac{1}{2}$	4	$3\frac{1}{2}$	$3\frac{1}{8}$
1	7	6	$5\frac{1}{4}$	$4\frac{1}{2}$	4	$3\frac{1}{2}$
$1\frac{1}{8}$	$7\frac{7}{8}$	$6\frac{3}{4}$	$5\frac{7}{8}$	5	$4\frac{1}{2}$	4
$1\frac{1}{4}$	$8\frac{3}{4}$	$7\frac{1}{2}$	$6\frac{1}{2}$	$5\frac{5}{8}$	5	$4\frac{3}{8}$
$1\frac{3}{8}$	$9\frac{5}{8}$	$8\frac{1}{4}$	$7\frac{1}{4}$	$6\frac{1}{4}$	$5\frac{1}{2}$	$4\frac{7}{8}$
$1\frac{1}{2}$	$10\frac{1}{2}$	9	8	7	6	$5\frac{1}{4}$
$1\frac{5}{8}$	$11\frac{3}{8}$	$9\frac{3}{4}$	$8\frac{1}{2}$	$7\frac{1}{2}$	$6\frac{1}{2}$	$5\frac{3}{4}$
$1\frac{3}{4}$	$12\frac{1}{4}$	$10\frac{1}{2}$	9	8	7	$6\frac{1}{4}$
2	14	12	$10\frac{1}{2}$	9	8	7

United States Navy Standard, MACHINERY'S Data Sheet No. 115. Explanatory note: Page. 38.

SETTING CORLISS ENGINE VALVE GEARS—I

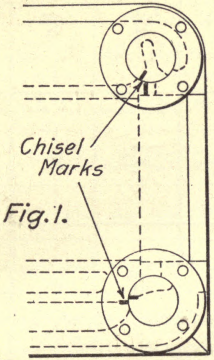


Fig. 1.

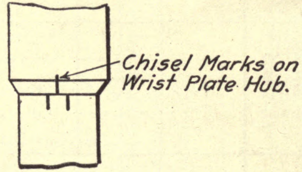


Fig. 2A.

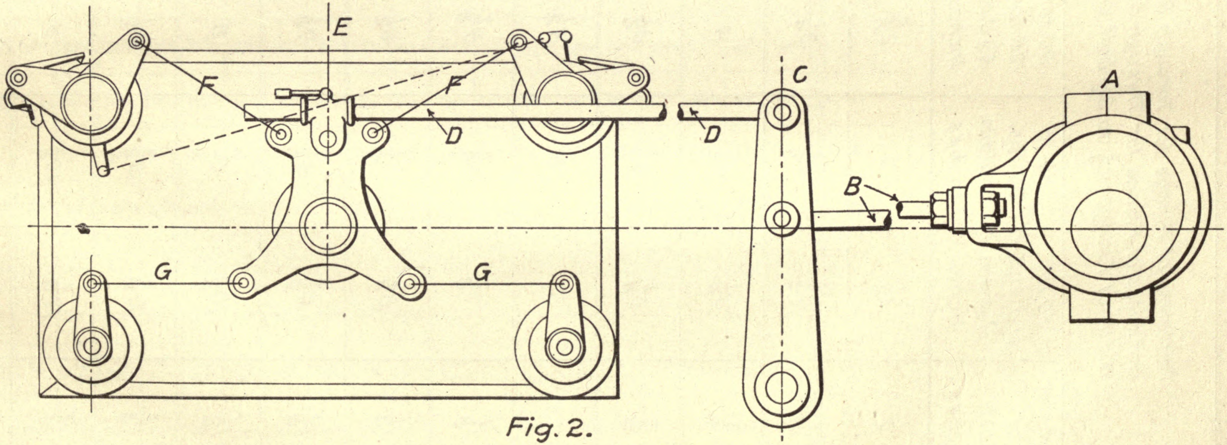


Fig. 2.

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SETTING CORLISS ENGINE VALVE GEARS—II

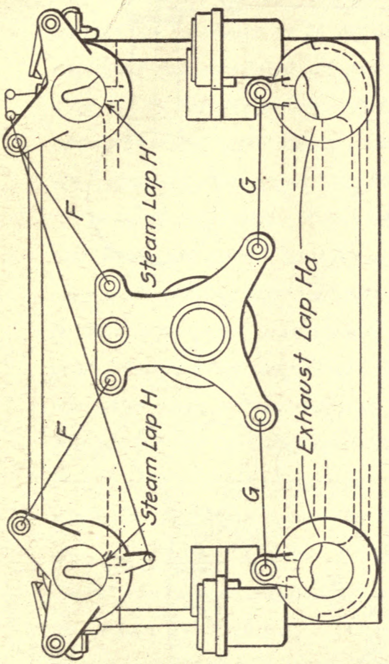

Fig. 3.

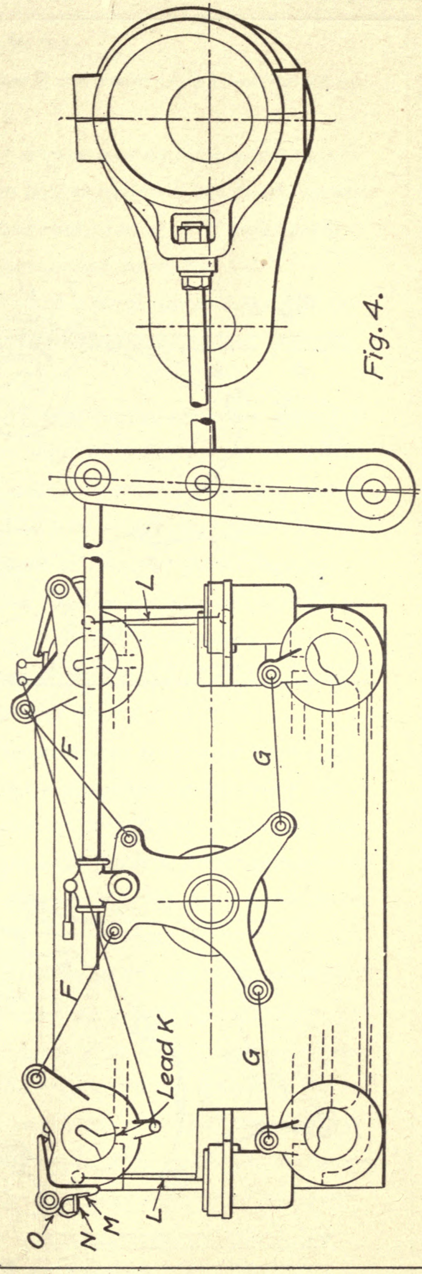

Fig. 4.

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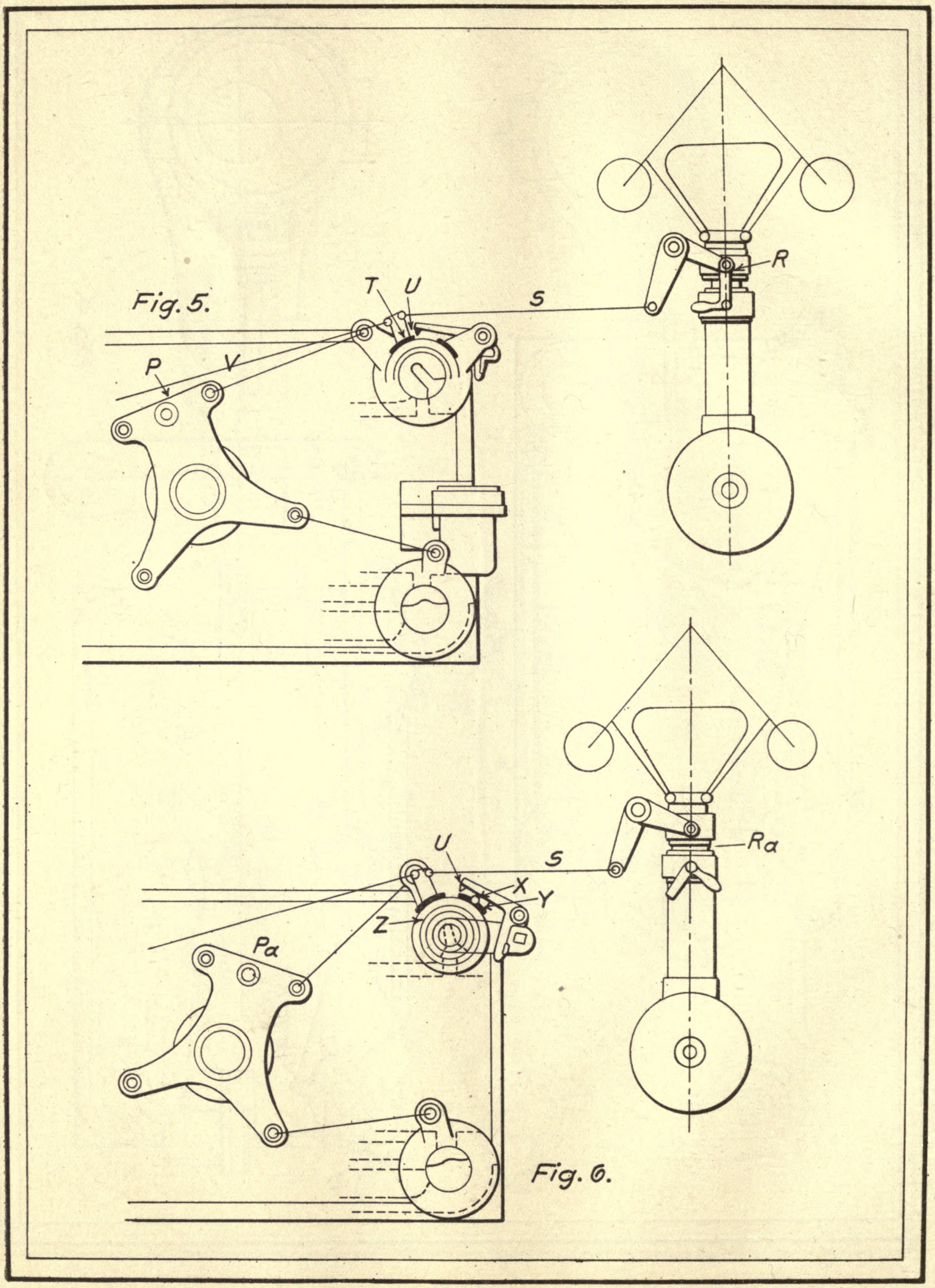
SETTING CORLISS ENGINE VALVE GEARS—III



SETTING CORLISS ENGINE VALVE GEARS—IV

Explanatory Notes.

Fig. 1. Working edges of valves and ports are shown by chisel marks on ends of valves and chambers

Fig. 2. To Find Length of Rods :- Turn engine over by hand until eccentric stands vertical, as shown at A; then adjust eccentric rod B until rocker stands vertical, as shown at C; then adjust reach rod D until wrist plate stands vertical, as shown at E. See marks on hub as in Fig. 2A.

Fig. 3. To Set Valves:- Adjust rods F until steam valves have the required lap, as shown at H. Adjust rods G until exhaust valves have the required lap, as shown at Ha.

Fig. 4. To Set Eccentric:- Put crank on dead center and move eccentric ahead of crank until steam valves show required lead, as at K. To Equalize Lead:- Fasten eccentric; then put crank on other center and note if the leads are equal. If not the same on both ends adjust rods F until both leads are equal. Caution About Length of Vac. Pot Rods:- In every case, when altering length of rods F, rod L to vacuum pot must be altered to suit. If rod L is too short, hook plate M will not pick up plate N and valve will not open. If rod L is too long, O will come down on top of N and either break the valve gear or vacuum pot, or bend rods F or L.

Fig. 5. To Set Cut-Off Cams:- Throw wrist plate over to extreme travel (by marks on hub Fig. 2A), as shown at P. Place governor on top latch as shown at R. Then adjust rod S until cut-off cam T nearly touches, but does not trip tail of hook U. Then throw wrist plate to other extreme of travel and adjust rod V until cam on head end just clears tail of hook, as shown at T and U.

Fig. 6. To Set Safety Cams:- Let governor down as far as it will go, as shown at R_a. Then move wrist plate over to extreme throw, as shown at P_a. Loosen screw X and slide safety cam Y on ring Z up under tail of hook U until hook trips at M. Slide cam along about 1/8 inch further and screw cam fast in this position. Set safety cam on other steam valve in the same manner. This insures that steam valves cannot open, as the hook cannot pick up the valve arm when governor is down at bottom. Hence governor must be raised up on stop before engine can be started.

CONDENSER AND AIR PUMP DATA—I

To Find Amount of Water Required to Condense One Pound Steam.

Let H = total heat in one pound steam at given pressure = (about 1190)

h = total heat in one pound water at temperature of the condensed steam

t = temperature of condensing water entering condenser

T = temperature of condensing water leaving condenser

Q = pounds water required to condense one pound steam

r = temperature of air pump discharge (= approx. h)

$$Q = \frac{H-h}{T-t} \quad \text{or} \quad Q = \frac{1190-r}{T-t} \text{ (see Table III)}$$

For jet condenser $T = r$ hence $Q = \frac{1190-T}{T-t}$ (see Table IV)

To Find Condensing Water per H.P. in (U.S.) Gallons.

One pound water at condenser temperature equals about 28 cubic inches

$$\frac{28}{231} = \frac{1}{8.25} \text{ gallons, hence } \frac{Q\text{(lbs)}}{8.25} = \text{U.S. gallons}$$

If S = pounds of steam required per H.P. per hour by engine

W = pounds steam condensed per hour

Q = pounds condensing water per pound steam

Then condensing water in U.S. gallons per hour $= \frac{\text{H.P.} \times Q \times S}{8.25}$ or

condensing water in U.S. gallons per minute $= \frac{\text{H.P.} \times Q \times S}{495}$

If $S = 20$, $Q = 25$: $\frac{20 \times 25}{495} = \frac{500}{495}$ = about one gallon per minute per H.P. which is a good practical allowance

Size of Injection Pipe.

Velocity of flow in injection pipe should not exceed 300 ft. per minute or 5 ft. per second

A close approximation is

$$\text{Diameter of pipe} = \sqrt{\frac{\text{pounds condensing water per hour}}{6000}} = \sqrt{\frac{\text{H.P.} \times S \times Q}{6000}}$$

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CONDENSER AND AIR PUMP DATA—II

To Find Size of Air Pump Required for Jet Condenser.

For vertical single acting pumps $D = 0.75\,W\,(Q+1)$

For horizontal double acting pumps $D = W\,(Q+1)$

Where :- D = pump displacement in cubic inches per minute

W = pounds steam condensed per hour

Q = pounds of injection water per pound steam

Ratio of pump displacement to volume of water is 1 to 1.613 for vertical single acting pumps and 1 to 2.143 for horizontal double acting.

To Find Size of Air Pump Required for a Surface Condenser.

For vertical single acting pumps $D = 5W$

For horizontal double acting pumps $D = 9W$

To Find Condensing Surface Required.

Allow one square foot cooling surface to each 10 pounds steam to be condensed per hour, cooling water at normal temperature not to exceed 75 degrees. In the tropics add at least 10 percent to the above. If there is an abundance of condensing water, as a keel condenser, or water works engine where all water pumped is run through condenser, surface may be much less. Allow from 20 to 35 pounds steam to each square foot surface.

Whitham's formula $S = \frac{WL}{180\,(T-t)}$

Where :- S = cooling surface in square feet

W = pounds steam condensed per hour

L = latent heat steam at condenser temperature

T = temperature of condenser, or air pump discharge

t = average temperature circulating water = $\frac{\text{initial} + \text{final temperature}}{2}$

For ordinary conditions this reduces to

$$S = \frac{17\,W}{180} \quad \text{or} \quad S = 0.0944\,W$$

Or one square foot cooling surface to about 10.6 pounds steam condensed per ordinary condenser with small horizontal brass tubes.

CONDENSER AND AIR PUMP DATA—III

Pounds Water Required to Condense 1 Pound Steam $Q = \frac{1190 - r}{T - t}$.

T−t	Temperature Air Pump Discharge.														
	90	95	100	102	104	106	108	110	112	114	116	118	120	125	130
5	220	219	218	217.6	217.2	216.8	216.4	216	215.6	215.2	214.8	214.4	214	213	212
10	110	109.5	109	108.8	108.6	108.4	108.2	108	107.8	107.6	107.4	107.2	107	106.5	106
15	73.3	73	72.7	72.5	72.4	72.3	72.1	72	71.9	71.7	71.6	71.5	71.3	71	70.7
20	55	54.7	54.5	54.4	54.3	54.2	54.1	54	53.9	53.8	53.7	53.6	53.5	53.2	53
25	44	43.8	43.6	43.5	43.4	43.4	43.3	43.2	43.1	43	42.9	42.9	42.8	42.6	42.4
30	36.7	36.5	36.3	36.3	36.2	36.2	36.1	36	35.9	35.9	35.8	35.7	35.7	35.5	35.3
35	31.4	31.3	31.1	31.1	31	31	30.9	30.8	30.8	30.7	30.7	30.6	30.5	30.4	30.3
40	27.5	27.4	27.2	27.2	27.1	27.1	27	27	26.9	26.9	26.8	26.8	26.7	26.6	26.5
45	24.4	24.3	24.2	24.2	24.1	24.1	24	24	23.9	23.9	23.9	23.8	23.8	23.7	23.5
50	22	21.9	21.8	21.8	21.7	21.7	21.6	21.6	21.6	21.5	21.5	21.4	21.4	21.3	21.2
55	20	19.9	19.8	19.8	19.7	19.7	19.7	19.6	19.6	19.6	19.5	19.5	19.4	19.4	19.3
60	18.3	18.2	18.2	18.1	18.1	18.1	18	18	18	17.9	17.9	17.9	17.8	17.7	17.7
65	16.9	16.8	16.8	16.7	16.7	16.7	16.6	16.6	16.6	16.5	16.5	16.5	16.5	16.4	16.3
70	15.7	15.6	15.6	15.5	15.5	15.5	15.4	15.4	15.4	15.4	15.3	15.3	15.3	15.2	15.1
75	14.7	14.6	14.5	14.5	14.5	14.4	14.4	14.4	14.4	14.3	14.3	14.3	14.3	14.2	14.1
80	13.7	13.6	13.6	13.6	13.6	13.5	13.5	13.5	13.5	13.4	13.4	13.4	13.4	13.3	13.2
85	12.9	12.8	12.8	12.8	12.8	12.7	12.7	12.7	12.7	12.6	12.6	12.6	12.6	12.5	12.5
90	12.2	12.2	12.1	12.1	12.1	12	12	12	12	11.9	11.9	11.9	11.9	11.8	11.8

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CONDENSER AND AIR PUMP DATA—IV

T-Temperature of Discharge	Pounds Injection Water Required per 1 Pound Steam Condensed $Q=\frac{1190-T}{T-t}$.													
	Entering Temperature of Injection Water = t.													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
90	20	22	24.4	27.5	31.4	36.7	44	55	73.3	110	220			
92	19.2	21.1	23.4	26.1	29.7	34.3	40.7	49.9	64.6	91.5	156.8	549		
94	18.6	20.3	22.4	24.9	28.1	32.2	37.8	45.7	57.7	78.1	121.8	274		
96	17.9	19.5	21.4	23.6	26.7	30.4	35.3	42.1	52.1	68.4	99.4	182.3		
98	17.3	18.8	20.6	22.7	25.4	28.7	33.0	39	47.5	60.7	84	136.5	364	
100	16.8	18.2	19.8	21.8	24.2	27.2	31.1	36.3	43.6	54.5	72.7	109	218	
102	16.2	17.5	19.1	20.9	23.1	25.9	29.4	34	40.3	49.5	64	90.7	155.4	544
104	15.7	17	18.4	20.1	22.2	24.7	27.8	31.9	37.4	45.2	57.2	77.6	120.7	271.5
106	15.3	16.4	17.8	19.4	21.3	23.6	26.4	30.1	35	41.7	51.6	67.7	98.5	180.7
108	14.8	15.9	17.2	18.7	20.4	22.5	25.2	28.5	32.8	38.6	47	60.1	83.2	135.2
110	14.4	15.4	16.6	18	19.6	21.6	24	27	30.9	36	43.2	54	72	108
112	14	15	16.1	17.4	18.9	20.7	22.9	25.7	29.1	33.6	39.9	49	63.4	89.8
114	13.6	14.5	15.6	16.8	18.2	19.9	22	24.5	27.6	31.6	37.1	44.8	56.6	76.9
116	13.3	14.1	15.1	16.3	17.6	19.2	21.1	23.3	26.2	29.8	34.6	41.3	51.1	67.1
118	12.9	13.7	14.7	15.8	17	18.5	20.2	22.3	24.9	28.2	32.5	38.3	46.6	59.6
120	12.6	13.4	14.3	15.3	16.5	17.8	19.5	21.4	23.8	26.7	30.6	35.7	42.8	53.5
122	12.3	13	13.9	14.8	15.9	17.2	18.7	20.5	22.7	25.4	28.9	33.4	39.6	48.5
124	12	12.7	13.5	14.4	15.4	16.7	18.1	19.7	21.8	24.2	27.3	31.4	36.8	44.4
126	11.7	12.4	13.1	14	15	16.1	17.4	19	20.9	23.1	26	29.6	34.3	40.9
128	11.4	12.1	12.8	13.6	14.5	15.6	16.9	18.3	20	22.1	24.7	27.9	32.2	37.9
130	11.2	11.8	12.5	13.2	14.1	15.1	16.3	17.7	19.3	21.2	23.6	26.5	30.3	35.3
132	10.9	11.5	12.2	12.9	13.7	14.7	15.7	17.1	18.6	20.3	22.5	25.2	28.6	33.1
134	10.7	11.2	11.9	12.6	13.4	14.3	15.3	16.5	17.9	19.6	21.6	24	27.1	31
136	10.4	11	11.6	12.3	13	13.9	14.8	16	17.3	18.8	20.7	22.9	25.7	29.2
138	10.2	10.7	11.3	12	12.7	13.5	14.4	15.5	16.7	18.1	19.8	21.9	24.5	27.7
140	10	10.5	11.1	11.7	12.4	13.1	14	15	16.2	17.5	19.1	21	23.3	26.2

Contributed by F. Douglas Wilkes, MACHINERY'S Data Sheet No. 121. Explanatory note: Page 38.

Example 1.—What weight of steam will be discharged per minute through a 3½-inch pipe, 100 feet long, with an initial pressure of 40 pounds, and a drop of 3 pounds?

$$47.8 \times 1.70 = 81.3 \text{ pounds.}$$

Example 2.—What size of pipe will be required to deliver 51.3 pounds of steam a distance of 100 feet, with an initial pressure of 60 pounds, and a drop of 2 pounds?

The factor for 60 pounds initial pressure and 2 pounds drop is 2.02, and $\frac{51.3}{2.02} = 25.4$, which in Table I corresponds to a 3-inch pipe.

Example 3.—What weight of steam will be discharged per minute through a 5-inch pipe, 600 feet long, with an initial pressure of 5 pounds, and a drop of ½ pound?

$$45.7 \times 0.40 = 18.3 \text{ pounds.}$$

The tables given may be applied to either power or heating work, or to any conditions where the quantity of steam used can be reduced to pounds per minute.

Engine Connections

Steam pipes for engine connections are commonly based on a velocity of 6,000 and 8,000 feet per minute for the steam and exhaust pipes respectively, assuming the entire cylinder to be filled with steam at each stroke. This gives approximately 0.14 square inches internal area per H. P. for the steam pipe and 0.20 square inches for the exhaust. For example, a 100 H. P. engine would require

$100 \times 0.14 = 14$ square inches, or a 4-inch steam pipe; and

$100 \times 0.20 = 20$ square inches, or a 5-inch exhaust pipe.

Tables V, VI and VII, page 11, give the diameters of pipe required for heating purposes.

Weight of Steam Discharged by Safety Valves

On page 12 a table is given of the weight of steam discharged per hour by safety valves. The amount of steam discharged by safety valves is a rather uncertain quantity, but this table may be considered as giving fair average values. The weights are calculated for a valve lift of 0.1 inch. If the lift of the valve is changed, the values given in the table should be multiplied by the factors given beneath the table for different valve lifts.

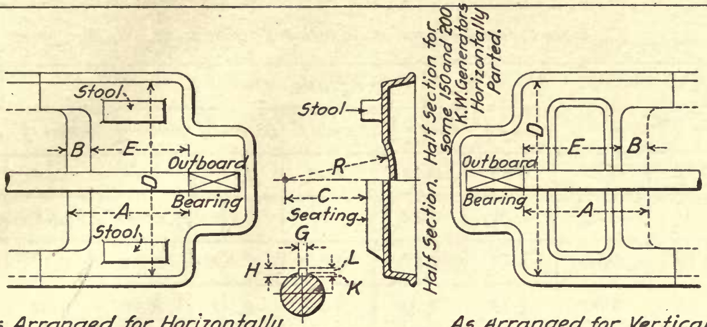
Diameters of Steam Pipes and Areas of Steam Ports

On page 13 is given a diagram by means of which the diameters of steam pipes and the areas of steam ports for engines with different piston speeds and velocities of steam may be determined. The notes in the lower right-hand corner of the diagram explain the significance of the various curves. The scales at the top and bottom of the diagram indicate the port area in square inches or the steam pipe diameter in inches, respectively.

For example, assume that it is required to find the port area for a steam engine, when the piston speed is 500 feet per minute, the piston area 20 square inches and the velocity of steam 6,000 feet per minute. Curve III gives the port area when the piston area equals 1, and the velocity of the steam is 6,000 feet per minute. In this case locate 500 on the left-hand vertical scale, giving the piston speed in feet per minute. Follow the horizontal line from 500 until it intersects the diagonal marked III. From the point of intersection, follow vertically up or down to the scale at top or bottom, where in this case the approximate graduation would be 0.085, which is the port area expressed in square inches for a piston area equal to one square inch. In the present case, where the piston area equals 20 square inches, the port area must be $20 \times 0.085 = 1.7$ square inch. The steam pipe diameter for the same conditions is found from curve VII, by

(Continued on page 38.)

DIRECT-CONNECTED ENGINE AND GENERATOR BASES



As Arranged for Horizontally Parted Generators.
Stools to be made and located to suit feet of horizontally parted generators. Builders of latter note that radius of outside of field piece must be $\frac{1}{4}$" to $\frac{1}{2}$" less than R.

As Arranged for Vertically Parted Generators.
Rectangular seatings to be made and located to suit bases of vertically parted generators.

All dimensions in inches

K.W. Capacity of Unit	R. P. M.	Armature bore		Diam. of engine shaft at armature fit		Space occupied on shaft between limit lines		B-Length of Extension Piece	C-Height of Shaft above Base	R	D-Width top of Sub-base	Key (feather)				Holding down Bolts	
		Center Crank	Side Crank	Center Crank Engine	Side Crank Engine	Long Class A	Short Class E					G Width	H Thickness	Depth K in Shaft	Above Shaft L	Diam.	No.
25	310	4	$4\frac{1}{2}$	$4+\frac{1}{1000}$	$4\frac{1}{2}+\frac{1}{1000}$	30	25	5	$23\frac{1}{2}$	flat	48	1	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	1	4
35	300	4	$5\frac{1}{2}$	$4+\frac{1}{1000}$	$5\frac{1}{2}+\frac{1}{1000}$	33	28	5	25	flat	54	1	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	1	4
50	290	$4\frac{1}{2}$	$6\frac{1}{2}$	$4\frac{1}{2}+\frac{1}{1000}$	$6\frac{1}{2}+\frac{2}{1000}$	37	31	6	28	flat	60	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	1	4
75	275	$5\frac{1}{2}$	$7\frac{1}{2}$	$5\frac{1}{2}+\frac{1}{1000}$	$7\frac{1}{2}+\frac{2}{1000}$	43	37	6	31	flat	66	$1\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	4
100	260	6	$8\frac{1}{2}$	$6+\frac{1}{1000}$	$8\frac{1}{2}+\frac{2}{1000}$	48	42	6	34	flat	72	$1\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	4
150	225	7	10	$7+\frac{2}{1000}$	$10+\frac{2}{1000}$	51	45	6	$37\frac{3}{4}$	$41\frac{1}{4}$	84	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{4}$	4
200	200	8	11	$8+\frac{2}{1000}$	$11+\frac{2}{1000}$	54	48	6	$42\frac{3}{4}$	$47\frac{1}{2}$	96	2	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{2}$	4

Contributed by L. C. Darier, MACHINERY's Data Sheet No. 125. Explanatory note: Page 38.

HORSEPOWER OF GASOLINE ENGINES—I

Table I. Horse-Power of Gasoline Engines.

Bore	Stroke: Bore + 0	Bore + 1/4"	Bore + 1/2"	Bore + 3/4"	Bore + 1"	Bore + 1 1/4"	Bore + 1 1/2"	Bore + 1 3/4"	Bore + 2"
2	0.72	0.80	0.89	0.98	1.08	1.17	1.25	1.35	1.44
2 1/4	1.01	1.12	1.22	1.34	1.45	1.57	1.68	1.81	1.90
2 1/2	1.39	1.53	1.67	1.81	1.95	2.09	2.23	2.37	2.51
2 3/4	1.85	2.02	2.19	2.36	2.53	2.70	2.87	3.04	3.20
3	2.40	2.60	2.80	3.00	3.21	3.40	3.61	3.81	4.00
3 1/4	3.06	3.28	3.52	3.76	3.99	4.22	4.45	4.70	4.92
3 1/2	3.81	4.09	4.36	4.63	4.90	5.18	5.45	5.72	6.00
3 3/4	4.71	5.02	5.34	5.65	5.97	6.28	6.60	6.91	7.23
4	5.71	6.06	6.42	6.78	7.13	7.50	7.85	8.20	8.55
4 1/4	6.84	7.24	7.64	8.05	8.45	8.85	9.25	9.66	10.06
4 1/2	8.25	8.68	9.16	9.62	10.08	10.54	10.96	11.41	11.89
4 3/4	9.57	10.07	10.57	11.09	11.58	12.08	12.59	13.09	
5	11.16	11.72	12.28	12.84	13.40	13.95	14.50		
5 1/4	12.92	13.54	14.15	14.76	15.40	16.00			
5 1/2	14.84	15.51	16.20	16.86	17.54				
5 3/4	16.96	17.70	18.42	19.19					
6	19.25	20.05	20.85	21.65					
6 1/4	21.78	22.61	23.50	24.33					
6 1/2	24.43	25.43	26.43						

Table is figured by assuming revolutions per minute = 1000, and mean effective pressure = 90 pounds per sq. inch, corresponding to 68 1/2 pounds compression. Multiply figures in table

Compression		Multiply by
For 60 pounds compression	by	0.933
70 "	"	1.011
80 "	"	1.066
90 "	"	1.100
100 "	"	1.111

Table II. Horse-Power of Gasoline Engines, figured from A.L.A. M.'s formula $\frac{D^2}{2.5}$ = H.P., where D is the diameter of the bore.

Bore, inches	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2
Horse Power	1.6	2.025	2.5	3.025	3.6	4.225	4.9
Bore, inches	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4
Horse Power	5.625	6.4	7.225	8.1	9.025	10.0	11.025
Bore, inches	5 1/2	5 3/4	6	6 1/4	6 1/2		
Horse Power	12.10	13.225	14.40	15.625	16.90		

Contributed by Morris A. Hall, MACHINERY'S Data Sheet No. 110. Explanatory note: Page 39.

HORSEPOWER OF GASOLINE ENGINES—II

Horse Power of Automobile Engines.

Based on the A.L.A.M. Standard Horse Power Formula, assuming a piston speed of 1000 feet per minute.

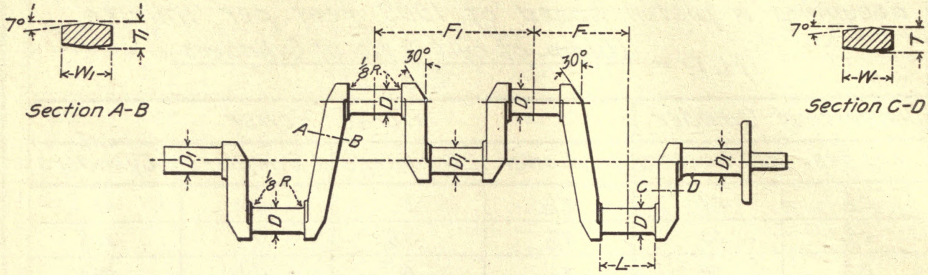
$$H.P. = \frac{(\text{Diam. of cyl.})^2 \times \text{No. of Cylinders}}{2.5}$$

Diameter of Cylinder		Horse Power			
Inches	Millimeters	1 Cylinder	2 Cylinders	4 Cylinders	6 Cylinders
2 1/2	64	2 1/2	5	10	15
2 5/8	68	2 3/4	5 1/2	11	16 1/2
2 3/4	70	3	6	12 1/10	18 1/5
2 7/8	73	3 5/16	6 5/8	13 1/4	19 7/8
3	76	3 3/5	7 1/5	14 2/5	21 3/5
3 1/8	79	3 15/16	7 13/16	15 5/8	23 7/16
3 1/4	83	4 1/4	8 1/2	16 9/10	25 2/5
3 3/8	85	4 9/16	9 1/8	18 1/4	27 2/5
3 1/2	89	4 9/10	9 4/5	19 3/5	29 2/5
3 5/8	92	5 1/4	10 1/2	20 1/4	31 3/5
3 3/4	95	5 5/8	11 1/4	22 1/2	33 3/4
3 7/8	99	6	12	24	36 1/16
4	102	6 2/5	12 4/5	25 3/5	38 2/5
4 1/8	105	6 13/16	13 5/8	27 1/4	40 9/10
4 1/4	108	7 1/4	14 1/2	28 9/10	43 4/5
4 3/8	111	7 5/8	15 5/16	30 5/8	45 15/16
4 1/2	114	8 1/10	16 1/5	32 2/5	48 3/5
4 5/8	118	8 9/16	17 1/8	34 1/4	51 3/5
4 3/4	121	9	18	36 1/10	54 1/10
4 7/8	124	9 1/2	19	38	57
5	127	10	20	40	60
5 1/8	130	10 1/2	21	42	63
5 1/4	133	11	22	44 1/10	66 1/5
5 3/8	137	11 9/16	23	46	69 1/10
5 1/2	140	12 1/10	24 1/5	48 2/5	72 3/5
5 5/8	143	12 5/8	25 5/16	50 5/8	75 15/16
5 3/4	146	13 1/4	26 1/2	53	79 1/2
5 7/8	149	13 13/16	27 5/8	55 1/4	82 9/10
6	152	14 2/5	28 4/5	57 3/5	86 2/5

A. L. A. M. Standard, MACHINERY'S Data Sheet No. 116. Explanatory note: Page 39.

PROPORTIONS OF AUTOMOBILE CRANK-SHAFTS—I

Four Cylinder 3 Journal Crank Shafts



B = Cylinder Bore
S_1 = Piston Stroke
S = Tensile Strength of Steel used
P = Total Pressure on Piston in Pounds
L_1 = Total or Aggregate Crank Journal Length

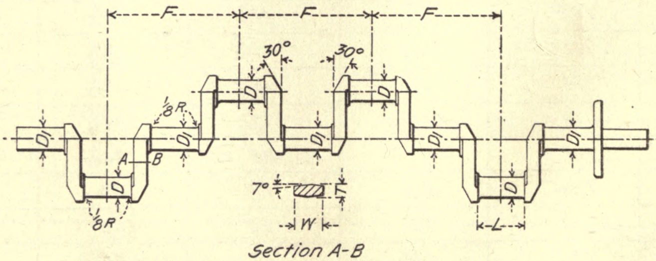
$$D = \sqrt[4]{\frac{P^2}{37.5 \times S}} \qquad L = \frac{P}{1200 \times D} \qquad F = 1.05 \times B$$

$$W = 1.32 \times D_1 \qquad T = \frac{0.96 D_1^3}{W^2}$$

$$D_1 = 2.6 \sqrt[3]{\frac{S_1 \times P}{S}} \qquad L_1 = 6.6 \times D_1 \qquad F_1 = 1.75 \times B$$

$$W_1 = 1.32 \times D_1 \qquad T_1 = \sqrt{\frac{0.534 \times D^3}{W_1}}$$

Four Cylinder 5 Journal Crank Shafts



B = Cylinder Bore
S_1 = Piston Stroke
S = Tensile Strength of Steel used
P = Total Pressure on Piston in Pounds
L_1 = Total or Aggregate Crank Journal Length

$$D = \sqrt[4]{\frac{P^2}{43.4 \times S}} \qquad D_1 = 2.6 \sqrt[3]{\frac{S_1 \times P}{S}} \qquad W = 1.32 \times D_1$$

$$L = \frac{P}{1530 \times D} \qquad L_1 = 9.25 \times D_1 \qquad T = \frac{0.96 D_1^3}{W^2}$$

$$F = 1.5 \times B$$

Contributed by Herbert C. Snow, MACHINERY'S Data Sheet No. 79. Explanatory note: Page 40.

PROPORTIONS OF AUTOMOBILE CRANK-SHAFTS—II

		Values of P for Different Compressions Gage							
Bore	Area	60	65	70	75	80	85	90	100
$3\frac{1}{2}$	9.62	2540	2690	2850	3000	3190	3380	3540	3800
$3\frac{5}{8}$	10.32	2720	2890	3060	3220	3430	3640	3800	4090
$3\frac{3}{4}$	11.04	2910	3090	3270	3450	3670	3890	4070	4370
$3\frac{7}{8}$	11.79	3110	3300	3490	3680	3920	4150	4340	4670
4	12.57	3320	3520	3720	3920	4170	4420	4600	4980
$4\frac{1}{8}$	13.36	3530	3760	3960	4170	4440	4700	4920	5280
$4\frac{1}{4}$	14.19	3740	3970	4200	4430	4700	4990	5220	5620
$4\frac{3}{8}$	15.03	3970	4220	4460	4730	5000	5300	5500	5950
$4\frac{1}{2}$	15.90	4200	4450	4700	4960	5280	5600	5850	6300
$4\frac{5}{8}$	16.80	4430	4700	4970	5240	5570	5910	6180	6650
$4\frac{3}{4}$	17.72	4670	4960	5240	5530	5880	6240	6480	7010
$4\frac{7}{8}$	18.66	4930	5220	5520	5820	6190	6560	6820	7380
5	19.63	5180	5500	5810	6120	6520	6900	7180	7740
$5\frac{1}{8}$	20.63	5440	5770	6100	6480	6880	7250	7540	8160
$5\frac{1}{4}$	21.65	5720	6060	6400	6750	7180	7660	7920	8560
$5\frac{3}{8}$	22.69	5990	6350	6700	7080	7520	7980	8340	8980
$5\frac{1}{2}$	23.76	6260	6640	7020	7400	7880	8350	8730	9400
$5\frac{5}{8}$	24.85	6560	6960	7350	7750	8240	8740	9140	9840
$5\frac{3}{4}$	25.97	6850	7260	7690	8100	8610	9140	9550	10250
$5\frac{7}{8}$	27.11	7150	7590	8030	8460	9000	9540	9980	10720
6	28.27	7460	7920	8360	8820	9390	9950	10340	11180

Contributed by Herbert C. Snow, MACHINERY'S Data Sheet No. 79. Explanatory note: Page 40.

following the horizontal line from 500 feet piston speed until intersecting curve VII, and from the point of intersection following the vertical line upward, the approximate reading on the upper scale being 0.29 inch. The piston diameter is 5.05 inches for a piston area of 20 square inches. Hence the steam pipe diameter required is $0.29 \times 5.05 = 1.46$ inch.

Steam Engine Design

On pages 14 to 17, inclusive, are given a number of simple rules and formulas for steam engine design, the details covered being the cylinder, the cylinder heads, cylinder head bolts, piston, piston rod, connecting-rod, crank-pin, valve stem, cross-head, wrist-pin and flywheel. For general guidance in steam engine design these rules and formulas will be found of considerable value to the steam engine designer.

Volume of Cylinders

On pages 18 and 19 are given two tables by means of which the volume of cylinders in cubic feet may be determined when the diameter and the stroke, both in inches, are given. For example, assume that the diameter of an engine cylinder is 16 inches and the stroke 22 inches. Then we find from the lower table on page 18 that the volume is 2.56 cubic feet. Of course, the table is as conveniently used in the reverse direction. If a cylinder volume of 4 cubic feet is required we find from the tables that a cylinder 18½ inches in diameter with a 26-inch stroke very closely fills the requirements. We also find that the cylinder 20 inches in diameter with a 22-inch stroke accurately answers the purpose. A number of other approximate combinations can also be determined from the tables.

Dimensions of Piston Rings, Stuffing Boxes, etc.

The table on page 21 gives dimensions of equal section and eccentric piston rings. These tables have been in use for several years in a steam engine building plant and found to answer the requirements. Dimensions are given for both lap cut and pin cut types of piston rings. On page 22 dimensions are given of stuffing boxes and glands, and on page 23 a table for the pitch of bolts in water and steam joints is provided. These tables will be found of value when designing steam engines and power plant equipment.

Setting Corliss Engine Valve Gears

On pages 24 to 27 inclusive are given directions for the setting of Corliss engine valve gears. The explanatory notes on page 27 give all the required information for the understanding of the illustrations on the three previous pages. The directions should be followed step by step, in order to obtain satisfactory results.

Condenser and Air Pump Data

On pages 28 to 31 inclusive are given formulas for the design of condensers and air pumps, and tables for aid in this work. The quantities found from the formulas are the amount of water required to condense one pound of steam, the amount of condensing water per horsepower, the size of injection pipe, the size of air pump required for a jet condenser, the size of air pump required for a surface condenser, and the required condensing surface. The tables on pages 30 and 31, marked III and IV, respectively, give the amount of water required to condense one pound of steam, according to the formulas given on page 28.

Direct-connected Engine and Generator Bases

On page 33 is given a table with a diagrammatical illustration showing a lay-out for direct-connected engine and generator bases, as arranged either for horizontally or vertically parted generators. In cases where the dimensions given cannot be directly applied to the case in hand, they will nevertheless be of value as guides in making similar lay-outs.

Horsepower of Gasoline Engines

The horsepower of a gasoline engine can, of course, be figured easily enough from the well-known formula

$$\frac{PLAN}{2 \times 33{,}000}$$

in which

$P =$ the mean effective pressure,

$L =$ the stroke in feet,

$A =$ the area of the piston or cylinder bore in square inches,

$N =$ the number of revolutions per minute.

In order, however, to save calculations a table can be prepared, giving at a glance the horsepower of gasoline engines, when the bore and the stroke are known. Such a table is given on page 34. This table shows the indicated horsepower or ideal power. To obtain the actual horsepower from the indicated horsepower given in the table, the figures stated must be multiplied by a factor based on the mechanical efficiency of the mechanism, which may vary from 94 to 70 per cent, and in some cases even less. As a fair average, however, 80 per cent may be used in the calculations. In the table on page 34, the bore is given in the left-hand vertical column, while the stroke is given in a horizontal line at the top; beginning with a stroke which is equal to the bore, which is found in the column headed "Bore + 0," the stroke increases in each successive column by ¼ inch up to the final column, which is 2 inches longer than the diameter of the bore. Thus the powers given are for engines varying from 2-inch diameter by 2-inch stroke, up to 6½-inch diameter by 7-inch stroke. The figures given, are, of course, for a single cylinder, and for multi-cylinder engines all that is required is to multiply by the number of cylinders. In figuring the table on page 34 the formula stated in the preceding column was used, the mean effective pressure being taken as 90 pounds per square inch, and the number of revolutions as 1,000 per minute. Ninety pounds mean effective pressure corresponds to a compression pressure of 68½ pounds. This may be verified by using Grover's well-known formula:

$$P = 2C - 0.01C^2,$$

where C is the compression.

This compression of 68½ pounds is taken as an average figure, but the compression may in reality vary all the way from 60 to 100 pounds, and racing automobiles have been built using a compression of 120 pounds.

As cars using 60 pounds compression, we may mention the Franklin and Covert cars; the Thomas and Moline cars use 65 pounds, while the Columbia cars use 100, and the Acme, 102. For these cases, the power corresponding may be found from the table by multiplying the figures there given by the following factors:

For 60	pounds comp.,	multiply by	0.933
" 70	" "	" "	1.011
" 80	" "	" "	1.066
" 90	" "	" "	1.100
" 100	" "	" "	1.111

As an example taken at random, illustrating the use of the table, let us find the power of a 5½-inch bore, 6-inch stroke, 4-cylinder engine. In the line of 5½-inch bore and in the column headed "Bore + ½ inch," we find the value 16.2, which, multiplied by 4, gives 64.8, as the indicated horsepower. Assuming a mechanical efficiency of 80 per cent, we get 51.8 H. P. as the actual horsepower. In Table II, page 34, is given the direct or actual horsepower of gasoline engines, as figured from the empirical formula

$$\frac{D^2}{2.5} = \text{horsepower}$$

which was recently adopted by the Association of Licensed Automobile Manufacturers. This formula is based on a piston speed of 1,000 feet per minute, which gives 2,000 R. P. M. for a 3-inch stroke, 1,500 R. P. M. for a 4-inch stroke, 1,200 R. P. M. for a 5-inch stroke, and 1,000 R. P. M. for a 6-inch stroke. This table would then compare with Table I only on the basis of 1,000 R. P. M., which would give a uniform stroke of 6 inches for all engines, regardless of diameter. As an example, take the same engine as above, 5½-inch diameter by 6-inch stroke, having 4 cylinders. In the table we find the horsepower given as 12.10. This, multiplied by 4, gives us 48.4, which is reasonably near the figure 51.8 for the horsepower, previously found, to indicate that the empirical formula previously given is approximately correct.

A more extended table of the horsepower of automobile engines as based upon the formula of the Association of Licensed Automobile Manufacturers, is given on page 35. The formula, in its complete form, is

$$H.P. = \frac{D^2 \times N}{2.5}$$

in which

D = diameter of cylinder, and

N = number of cylinders.

The table gives the horsepower of automobile engines as calculated from this formula for engines having one, two, four and six cylinders, with the diameter of the cylinder varying from 2½ to 6 inches.

Proportions of Automobile Crankshafts

On pages 36 and 37 are given diagrams and a table for designing automobile crankshafts. The formulas used are given on page 36, and the values of the total pressure on the piston in pounds, P, for different compressions, are given in the table on page 37, for varying bores.

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No. 17. Strength of Cylinders—Formulas, Charts, and Diagrams.

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